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# Multi-scale analysis of northern goshawk (*Accipiter gentilis*) breeding habitat in New Hampshire

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**MULTI-SCALE ANALYSIS OF NORTHERN GOSHAWK (*ACCIPITER  
GENTILIS*) BREEDING HABITAT IN NEW HAMPSHIRE**

By

Angela Karedes  
Baccalaureate Degree (BS), University of New Hampshire 2007

THESIS

Submitted to the University of New Hampshire  
in Partial Fulfillment of  
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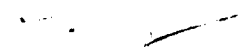
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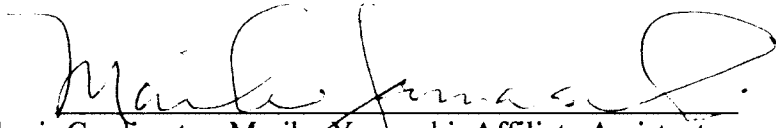
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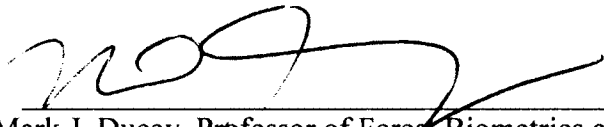


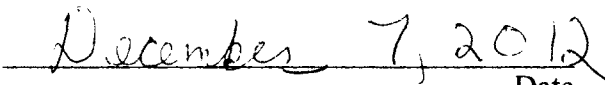
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## ABSTRACT

### MULTI-SCALE LAND COVER ANALYSIS OF NORTHERN GOSHAWK (*ACCIPITER GENTILIS*) BREEDING HABITAT IN NORTHERN NEW ENGLAND

By

Angela Karedes

University of New Hampshire, December, 2012

I compared characteristics of northern goshawk (*Accipiter gentilis*) breeding areas (n = 44) to available habitat (n=100 random sites) across New Hampshire at four spatial scales (162, 405, 809 and 1619 ha). Differences in forest composition between breeding areas and available habitat were present (Hotelling-Lawley  $p = 0.009$ ) with least squares analysis revealing hay/pasture ( $p < 0.001$ ) and beech/oak ( $p = 0.004$ ) present less than expected and birch/aspen ( $p = 0.039$ ) and white pine ( $p = 0.008$ ) present more than expected, within breeding areas. Analyses also showed that as distance from the core of the breeding area (centered on the nest tree) increased differences between breeding areas and available habitat decreased. Results suggest that, in New Hampshire, goshawks select breeding areas based on nest stand composition and landscape-scale patterns.

## **CHAPTER I**

### **INTRODUCTION**

#### **Species Description**

The northern goshawk (*Accipiter gentilis* Linnæus 1758) is a secretive, forest raptor found in temperate and boreal forests throughout the Holarctic (Squires and Reynolds 1997). Usually cryptic in nature, goshawks are an elusive species, and often difficult to detect (Speiser and Bosakowski 1991, Kennedy and Stahlecker 1993, Roberson et al. 2005). An exception to their cryptic behavior is during the breeding season when they aggressively defend their nesting area (Speiser and Bosakowski 1991, Squires and Reynolds 1997, Reynolds et al. 2005). Known for boldly attacking humans, goshawks will readily strike any intruder approaching their nest (Speiser and Bosakowski 1991, Squires and Reynolds 1997, Bosakowski 1999). For this reason, many researchers conduct goshawk studies during the breeding season, when activity is centered around the nest area (Kennedy et al. 1994) and detection rates are increased (Kennedy and Stahlecker 1993).

The goshawk is a sexually dimorphic species, with the larger female averaging 61 cm in total length and males averaging 55 cm. The average weight for a female goshawk is between 860 and 1,364 g and for a male between 631 and 1,099 g. Wingspans range from 105–115 cm for females and 98–104 cm for males. Adults are brown-gray to slate-gray on upperparts, with a black cap, and a pronounced white strip over the eyebrow,

known as the superciliary line. Adult goshawk underparts are light with fine, gray, horizontal barring and eye color ranging from orange to dark red. Distinct vertical brown barring and yellow eyes mark juveniles in their first year (Squires and Reynolds 1997).

### **Species Range**

Several weakly differentiated subspecies of goshawk have been recognized globally (Stresemann and Amadon 1979). Of the three subspecies identified within North America; *A.g. atricapillus* (Wilson 1812); *A. g. laingi* (Taverner 1940); and *A. g. apache* (Van Rossem 1938), only *atricapillus* is currently recognized by the American Ornithologist's Union (AOU 1998). The largest of the three *Accipiters* found in North America, goshawks occur in Alaska (to the edge of the boreal forest), through all Canadian Provinces, south through the U.S. western and mid-western states to south-central Mexico, east through the north-central and Great Lake states, through the central Appalachian and into the northeastern region of the U.S. The southern limit in the eastern U.S. reaches to West Virginia (Fig. 1) (Squires and Reynolds 1997, Bosakowski 1999). Insufficient data exists to explain the southern limit of goshawks in the eastern region of the U.S. (Kennedy 1997).

### **Behavior**

Goshawks have been characterized as both an opportunistic and a generalist predator (Squires and Reynolds 1997, Squires and Kennedy 2006). The diversity of goshawk prey species varies both regionally and seasonally, with a prey base that often

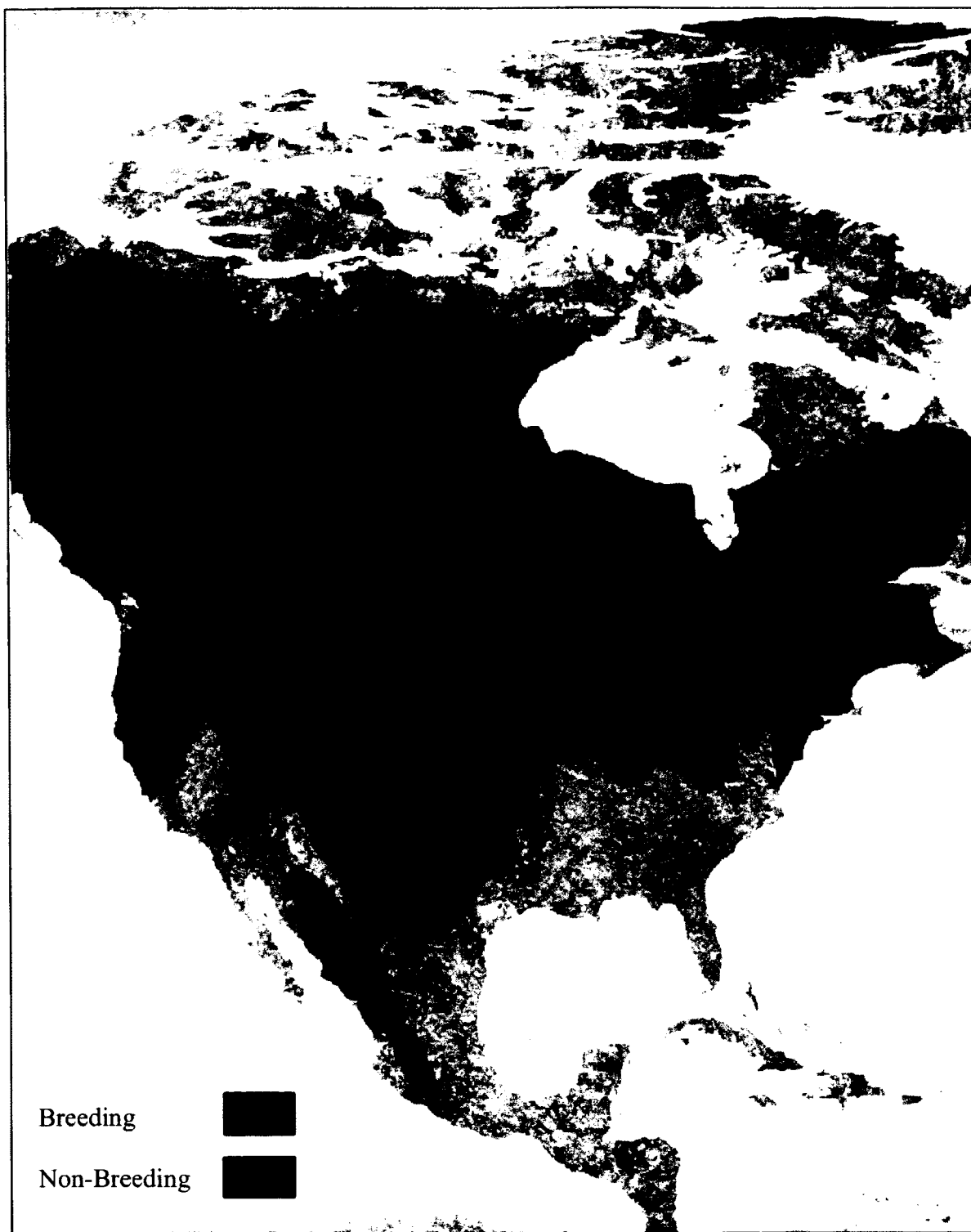


Figure 1. Northern goshawk range map for North America. Data used from NatureServe available at <http://www.natureserve.org/infonatura>.

includes both avian and mammalian species (Squires and Reynolds 1997, Bosakowski 1999). Described as short duration, sit-and-wait predators, goshawks will perch briefly, to search for prey before moving to a new perch (Kenward 1982, Squires and Reynolds 1997, Bosakowski 1999). Their short, wide wings and long, rudder-like tail enable them to accelerate rapidly and maneuver quickly through forested habitat (Squires and Reynolds 1997). Their aggressive nature and rapid maneuvering skills may make them appear reckless, crashing through brush and snapping branches, in pursuit of their prey; however they are very proficient hunters (Squires and Reynolds 1997, Bosakowski 1999). Goshawk prey species often include, but are not limited to ground and tree squirrels; hares and rabbits; woodpeckers; grouse; medium- to large-sized songbirds and waterfowl (Reynolds et al. 1992, Bosakowski 1999). The diverse landscapes found within, and surrounding, goshawk breeding areas may be important because they potentially support the wide variety of prey species goshawks consume (Reynolds et al. 1992). This varied prey base allows a generalist predator like the goshawk to substitute one prey species for another if abundance of a common prey species declines (Rutz and Bijlsma 2006, Salafsky et al. 2007).

Although goshawks aggressively defend the nest in daylight hours, they are less able to do so at night, when nocturnal predators like owls may prey on nestlings and even the occasional adult (Rohner and Doyle 1992). Great horned owls (*Bubo virginianus*) are common predators of goshawks (Rohner and Doyle 1992, Boal and Mannan 1994, Woodbridge and Detrich 1994, Ward and Kennedy 1996). Other species known to prey on goshawks include pine martens (*Martes americana*) (Paragi and Wholecheese 1994) and fishers (*Martes pennanti*) (Erdman et al. 1998). There are also reports of overwinter



killing of goshawks by golden eagles (*Aquila chrysaetos*) and bald eagles (*Haliaeetus leucocephalus*) in the Rocky Mountains (Squires and Ruggiero 1995).

Goshawk reproduction and nestling survival are strongly correlated to prey abundance and, in years of scarce food supply, goshawks may even forego breeding for that year (Ward and Kennedy 1996, Salafsky et al. 2005, Reynolds et al. 2006, Salafsky et al. 2007). Doyle and Smith (1994) reported a decline in goshawk numbers as abundance of snowshoe hare (*Lepus americanus*) declined during the 10-year boreal cycle in southwestern Yukon, Canada. In years of low food availability adults may spend more time away from the nest in search of prey, increasing the vulnerability of nestlings to attack by diurnal predators (Rohner and Doyle 1992, Ward and Kennedy 1996, Dewey and Kennedy 2001, Boal et al. 2005a). Absence of an adult, combined with scarce food resources, may also increase sibling rivalry and the likelihood of siblicide among nestlings (Boal and Bacorn 1994, Dewey and Kennedy 2001, M. Yamasaki, USDA Forest Service pers. comm.). Abundant food resources indirectly protect nestlings by allowing the female to spend less time foraging and more time defending the nest, thereby reducing the loss of nestlings through predation (Ward and Kennedy 1996) and siblicide (Dewey and Kennedy 2001, M. Yamasaki, USDA Forest Service pers. comm.).

### **Nesting Habits**

Goshawks build nests in deciduous, coniferous or mixed forests (Squires and Reynolds 1997) in areas that are strongly associated with late seral stage forest structure (Reynolds et al. 1982, Speiser and Bosakowski 1987, Squires and Ruggiero 1996, Daw and DeStefano 2001). Goshawks build large stick nests in primary crotches of deciduous

hardwoods or at the base of horizontal limbs in coniferous species (Speiser and Bosakowski 1987). Nests are most often located in the lower one-third of, or just below, the forest canopy (Reynolds et al. 1982, Speiser and Bosakowski 1987). Nests site composition usually consists of larger diameter trees (Siders and Kennedy 1994, Squires and Ruggiero 1996), an open understory (Reynolds et al. 1982, Squires and Ruggiero 1996) and dense canopy cover (Reynolds et al. 1982, Hayward and Escaño 1989).

Behavioral and telemetry studies have delineated breeding home range sizes between 500 and 4,000 ha (~1,200-9,800 acres) with a median range of approximately 2000-2,400 ha (~5000-6,000 acres) (Reynolds 1983, Reynolds et al. 1992, Iverson et al. 1996, Squires and Reynolds 1997, Boal et al. 2003). Exceptionally large home ranges were identified in Alaska (median home range was 3,834 ha for females and 4,625 ha for males) but this may be related to a different method of data collection (aerial telemetry) compared to other studies (Iverson et al. 1996).

Goshawks utilize the landscape at several spatial scales (Reynolds et al. 1992, Kennedy et al. 1994), with breeding home ranges consisting of three spatial components: a nest site, a post-fledging-family area (PFA) and a foraging area (Reynolds et al. 1992, Kennedy et al. 1994). The nest site, defined as the vegetative and topographic area immediately surrounding the nest tree, is approximately 10-12 ha (~25-30 acres). The PFA, estimated to be approximately 170 ha (~420 acres), includes the nest site and the area immediately surrounding the nest site. Fledgling goshawks remain in the PFA while still dependent on the adults for food (Reynolds et al. 1992, Kennedy et al. 1994) and use this area to hone flight skills and practice hunting techniques (Kennedy et al. 1994, Daw and DeStefano 2001). The PFA may also be a defended portion of the breeding territory

(Speiser and Bosakowski 1991, Reynolds et al. 1992, Kennedy et al. 1994). The foraging area includes the PFA and the area immediately surrounding the PFA (Reynolds et al. 1992, Kennedy et al. 1994). The total range size of breeding goshawks is estimated at approximately 2,186 ha (~5,400 acres) (Reynolds et al. 1992, Kennedy et al. 1994) but range sizes can be highly variable and are likely influenced by factors such as parental experience, brood size and food availability (Kenward 1982, Kennedy et al. 1994).

Several studies show breeding goshawks tend to have strong fidelity to breeding territories and some birds may occupy a single territory for several years in a row (Reynolds 1983, Crocker-Bedford 1990, Speiser and Bosakowski 1991, Detrich and Woodbridge 1994, Reynolds and Joy 1998, Mahon and Doyle 2005, M. Yamasaki, USDA Forest Service pers. comm.). Goshawks build alternate nests (Fig. 2) within their breeding areas and researchers have reported as few as one or as many as nine alternate nests within a single breeding territory (Reynolds 1983, Speiser and Bosakowski 1991, Reynolds et al. 1994, Woodbridge and Detrich 1994, M. Yamasaki, USDA Forest Service pers. comm.). Alternate nests may be located in more than one stand within the territory and may be separated by as little as a few hundred meters or as far apart as two kilometers (Reynolds et al. 1978, Woodbridge and Detrich 1994, Bosakowski 1999). Along the New York-New Jersey border, Speiser and Bosakowski (1991) found from one to five alternate nests within territories and re-occupancy of a territory often involved a different nest than was used in the previous year.

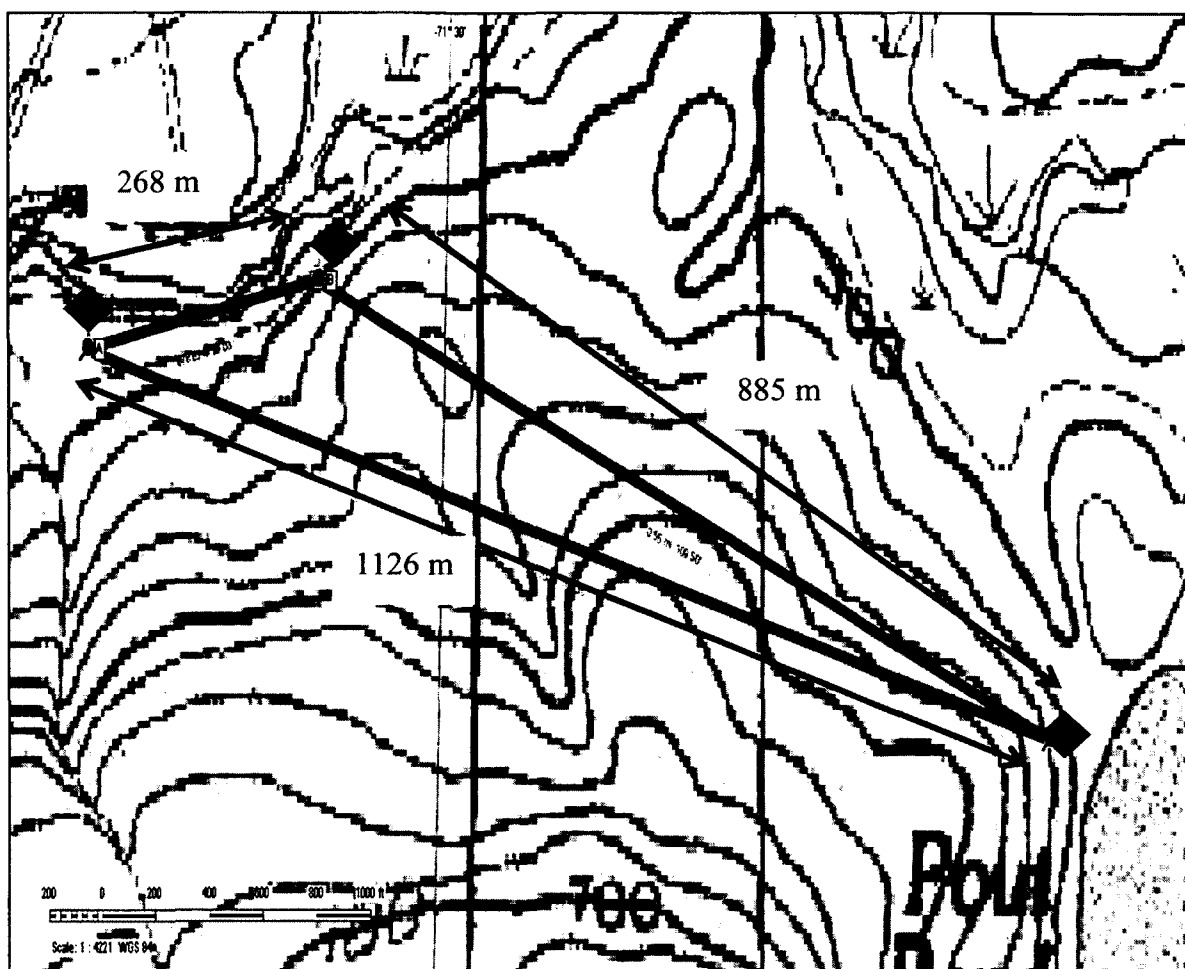


Figure 2. Three alternate northern goshawk nests located within a single breeding territory in central New Hampshire.

## **Species Status**

Estimating goshawk populations is extremely challenging for a variety of reasons (Kennedy 1997, Reynolds et al. 2005). It is financially prohibitive to monitor goshawk populations due to the considerable time and effort involved in studying a species that is widely distributed, uses complex habitats and breeds in low densities with annually variable breeding rates (DeStefano et al. 1994, Reynolds et al. 1994, Kennedy et al. 1994, Boal et al. 2005a). The building of alternate nests within breeding territories compounds the difficulties of detection in this elusive species (Woodbridge and Detrich 1994, Reynolds 1983, Reynolds et al. 1994, Kennedy 1997, Reynolds and Joy 1998, Reynolds et al. 2005, M. Yamasaki, USDA Forest Service pers. comm.). Migration counts and Christmas bird counts are not reliable sources for tracking goshawk population trends due to low numbers observed at counting stations and the goshawk's irruptive migratory behavior (Titus and Fuller 1990, Andersen et al. 2004). The literature indicates that goshawk population densities are highly variable, both spatially and temporally, making evaluation of population trends speculative at best (Squires and Reynolds 1997, Kennedy 1997, Reynolds and Joy 1998).

The relationship of nesting goshawks to mature forest structure has led some researchers to express concern about negative impacts on breeding goshawks from logging and fragmentation of forestland (Crocker-Bedford 1990, Reynolds et al. 1992, Hargis et al. 1994). Some comparisons have been drawn between goshawks and the northern spotted owl (*Strix occidentalis caurina*), an endangered species that is partially reliant on older forest structure and found to be negatively impacted by timber harvesting

(DeStefano1998). Goshawk do nest in areas characterized by mature forest structure, (Reynolds et al.1982, Reynolds 1983, Speiser and Bosakowski 1987, Crocker-Bedford 1990, McGrath et al. 2003) but as distance from the nest increases the landscape becomes more diverse, containing several different land cover types and forest seral stages (McGrath et al. 2003, DeStefano et al. 2006). The use of a wider variety of forest types and forest seral stages, compared to those used by spotted owls, suggests that goshawks may be less sensitive to habitat alteration (DeStefano1998).

The northern goshawk has been cited in several, unsuccessful petitions, initiated by non-governmental groups, to list goshawk populations in the United States, west of the 100<sup>th</sup> meridian, as threatened or endangered under the Endangered Species Act (ESA) (USDI FWS 1992, 1995, 1998a, 1998b, 2005). To protect species viability and prevent trends toward federal listing under the ESA (Woodbridge and Hargis 2006) the United States Forest Service (USFS) has designated the northern goshawk a Regional Forester's Sensitive Species. Currently the goshawk is designated a Sensitive Species in six of the nine USFS administrative regions: regions 2 (Rocky Mountain), 3 (Southwestern), 4 (Intermountain), 5 (Pacific Southwest) and 10 (Alaska) (USDA Forest Service 2005). Region 9, where this study was located, designates the goshawk as a sensitive species in some areas but not on the White Mountain National Forest in New Hampshire. Concern regarding negative impacts on goshawk breeding habitat by human activity, particularly from timber harvesting, is widely debated among experts (Crocker-Bedford 1990, Kennedy 1997, Kennedy 2003, Greenwald et al. 2005, Mahon and Doyle 2005, Reynolds 2006, Reynolds et al. 2008). Despite concerns regarding goshawk nesting habitat, globally, the northern goshawk is considered stable throughout its range and is ranked as

a species of least concern by the International Union for Conservation of Nature (IUCN 2008).

### **Current Knowledge of Goshawks in the United States**

Current knowledge and management strategies concerning goshawk habitat in the U.S. are based on research conducted, primarily, in the western and southwestern regions of the country (Boal et al. 2003, Bosakowski 1999, Reynolds et al. 1992). Few goshawk studies have been conducted in the eastern region of the U.S. and there are no published data on goshawk habitat in the northeastern New England states (Speiser and Bosakowski 1987, Bosakowski 1999, DeStefano 2005, M. Yamasaki, USDA Forest Service pers. comm.). Due to this lack of information, goshawk-habitat relations in the northeast are poorly understood (DeStefano 2005) and management strategies to conserve goshawk habitat in this region are limited (M. Yamasaki, USDA Forest Service pers. comm.).

Across the U.S. differences in land cover type, topography, spatial distribution of habitat patches, weather, landownership patterns and land management strategies vary widely across regions (Boal et al. 2003, Smith et al. 2001, Bosakowski 1999). Regional climatic regimes are strongly influenced by latitudinal location, coastal orientation and changes in elevation (McNab et al. 2005, Pidwirny 2006). Western regions are characterized by a variety of climatic zones influenced by high elevation mountain ranges, with several points over 4200 meters, inter-mountainous regions of low valleys and flatlands, desert areas, and strong maritime influences from the Pacific Ocean (Smith et al. 2001). In comparison to western regions, the northeast has lower elevations and a less variable climate (see study area for a more detailed description).

The west also consists of predominately high-elevation coniferous forests (Smith et al. 2001), while the more heavily forested northeastern region consists of mixed coniferous-deciduous forest, with a transitional zone between the boreal forest in the north and deciduous forest in the south (McNab et al. 2005). Another important difference between these two regions is in landownership patterns of forested areas. In the western portions of the U.S. forestland is primarily in public holdings (between 72-75%); whereas, in the northeast about 75% of forestland is held in private ownership (Smith et al. 2009). This distinct difference in the pattern of ownership of eastern forestland has potentially important implications for mechanisms used to develop management strategies for the northern goshawk in New Hampshire.

In response to local variations, a wide-ranging species like the goshawk may develop regional specializations in the selection and utilization of habitat (Penteriani 2002, Bosakowski 1999). Strategies designed to manage goshawk habitat in the U.S., based on knowledge acquired from western studies, may only be applicable to breeding populations and habitat conditions of western and southwestern forests (Bosakowski 1999, Boal et al. 2003, Kennedy 2003, Boal et al. 2005b). Therefore, management protocols for goshawk habitat in northeastern forests should not be based solely on the data from existing studies (Bosakowski 1999, Boal et al. 2003, Boal et al. 2005b).

Evaluation of the complex needs of the northern goshawk in the northeast requires a method that efficiently locates goshawk nests, as well as the ability to assess goshawk habitat at multiple scales surrounding nest areas (Reynolds et al. 1992, Kennedy et al. 1994). Patterns in habitat use are the result of a process of selection and require evaluation at scales appropriate to the focal species. Johnson (1980) discusses a



hierarchical habitat selection process ranging from macrohabitat selection (i.e., geographic range based on suitable climate) to microhabitat choices of nesting and feeding areas. The large home ranges and variety of forest types and conditions used by breeding goshawks makes it likely that goshawks choose nest sites based, at least partially, on landscape-scale patterns and processes, not merely stand-level characteristics (McGrath et al. 2003). Assessment of landscape-scale patterns surrounding goshawk use areas could assist land managers in the northeast to gain a better understanding of goshawk habitat requirements and aid in assessing viability of populations in this region.

### **Objective and Hypotheses**

The main objective of this study was to gain a better understanding of how northern goshawks use the northeastern landscape. To achieve this goal I attempted to describe landscape-scale characteristics of goshawk breeding areas within New Hampshire at four spatial scales. I also mapped habitat distribution patterns of breeding goshawks within New Hampshire.

It is well documented that goshawk breeding areas contain at least three spatial components (Reynolds et al. 1992, Kennedy et al. 1994) and that vegetative structure of a goshawk breeding area is often distinctly different from the surrounding landscape (Reynolds et al. 1982, Speiser and Bosakowski 1987, Squires and Ruggiero 1996, Daw and DeStefano 2001). I hypothesized that there would be a differences between the land cover composition and topographic features of areas used by breeding goshawks, compared to the habitat available in the surrounding landscape. I also hypothesized that the differences between goshawk breeding areas and the surrounding landscape would be

most significant at the core of the breeding area, which includes the nest site and the PFA, and that these differences would decrease as distance from the nest increased.

## **CHAPTER II**

### **METHODS**

#### **Study Area**

New Hampshire is one of the six New England states and is located within the Northeast and central Appalachian Mountains Goshawk bioregion as described in Woodbridge and Hargis (2006). Total land area for the state is 23,290 square kilometers (14,472 square miles) of which approximately 81% is forested (SPNHF 2005).

New England is predominantly a temperate humid zone influenced by both tropical and polar air masses and some maritime influences from the Atlantic Ocean (McNab et al. 2005). This region is characterized by cold winters (average January temperatures from -14°C to 3.9°C) and warm summers (August temperatures between 16.7° C and 24°C) (NRCC 2009). New England states experience an average annual rainfall between 92 and 125 cm and average snowfall between 51 and 285 cm (NRCC 2009) across most of the region, but higher averages of precipitation can occur at higher elevations. New England contains many mountain peaks greater than 1,219 meters (4,000 feet) with the highest elevation point located on top of New Hampshire's Mount Washington at 1,916.6 meters (6,288 feet) (USGS 2005). Mount Washington experiences extreme weather conditions, maintaining higher than average rainfall (> 254 cm) and snow accumulations (> 660 cm) for the region (NRCC 2009). The lowest point of elevation in New England is at sea level (USGS 2005).

New Hampshire is the second most forested state in the conterminous U.S, behind Maine, and contains all six forest regions found in New England. New England forest regions are named for the predominate vegetation type that occurs within each region and include : spruce-fir; northern hardwoods-spruce; northern hardwoods; transitions hardwoods-white pine; central hardwoods-hemlock-white pine; and pitch pine-oak (classified by Braun 1950, Kuchler 1964 and described in DeGraaf and Yamasaki 2001 and DeGraaf et al. 2006).

### **New England History**

New England has a long history of land conversion dating back to pre-European settlement (DeGraaf and Yamasaki 2001). Native Americans altered forested landscapes by cutting fuelwood and periodically burning forests to facilitate settlements, drive game and clear fields for agricultural purposes (DeGraaf and Yamasaki 2001, DeGraaf et al. 2005, DeStefano 2005), although the intensity of land alterations by aboriginal peoples is unclear (Foster et al. 1998). Post-European settlement saw dramatic increases in human population, changes in land-use, and extreme alterations to the vegetative structure of the landscape (Foster et al. 1998, DeGraaf and Yamasaki 2001, Foster 2002). Land was cleared extensively for agricultural purposes starting in the middle of the 17<sup>th</sup> century and continued through the middle of the 19<sup>th</sup> century, by which time 75% of arable land in southern and central New England was in pasture and cropland (DeGraaf and Yamasaki 2001). By the late 19<sup>th</sup> and early 20<sup>th</sup> centuries farm abandonment gave way to reforestation of the region, with approximately 60% of southern, and 80-90% of northern New England forested near the end of the 20<sup>th</sup> century (USDA Forest Service 1997-2002).

These changes to the landscape in New England have had profound effects on wildlife dynamics in the region (DeGraaf and Yamasaki 2001, Foster et al. 2002). Open-country and early successional habitat species, that expanded their range during land clearing, are now in decline and forest species are expanding into or re-populating areas where forests have recurred (Litvaitis 1993, DeGraaf and Yamasaki 2001). During the height of land clearing, goshawks were apparently absent from the northeastern region and have since returned, in the past century, contemporaneously with reforestation (DeStefano 2005, DeGraaf and Yamasaki 2001, Boyce et al. 2006). Currently, the northern goshawk is characterized as a resident breeder throughout New England (DeGraaf and Yamasaki 2001).

The New England landscape is still experiencing considerable changes from a growing human population and shifting land-use patterns. Land use changes are most evident in New Hampshire, which has the fastest growing population in New England (SPNHF 2005). Growing at twice the rate of other New England states, New Hampshire's rural areas are rapidly developing into exurban and urban landscapes (SPNHF 2005, Morin 2011).

New Hampshire has been losing forestland, primarily in the form of development, over the last several decades (Kingsley 1976, SPNHF 2005). Assessments of New Hampshire forests by the U.S. Forest Service's Forest Inventory and Analysis (FIA) unit show 87% of total land area was forested in 1983 (Frieswyk and Malley 1985) and a decline of 3%, to 84% of forested area, had occurred by 1997 (Frieswyk and Widman 2000). A current estimate of forest cover in New Hampshire is just over 81%, according

to analysis of satellite data conducted in 2001 (Justice et al. 2002) and further decline, to less than 80% forest cover, is projected for the year 2025 (SPNHF 2005).

### **Data Collection**

Locations of northern goshawk breeding areas (n=44) (Fig. 3) were acquired from existing, unpublished data of a USDA Forest Service study of goshawk nesting stands in New Hampshire and southern Maine. Analyses were restricted to nest sites from the New Hampshire dataset. Nest site locations were collected non-systematically during the 1995-2007 field seasons by visual surveys of historic nest sites, broadcast surveys, reports from private landowners and foresters, postings at trailheads and notices on the NH bird list serve. Nesting activity was confirmed by visual sighting of goshawks, eggshell fragments, goshawk feathers, whitewash (fecal droppings) or plucking posts near a nest location. A handheld Garmin GPS unit was used to mark geographical coordinates of nest trees. Breeding activity occurred at all nests for at least one of the years in which data were collected but all nest sites were not active in all years. A nest was considered active even if breeding attempts were unsuccessful.

### **GIS Analysis**

This study consists of a use-versus-availability, multi-scale analysis of cover types and an analysis of topographical features of goshawk breeding areas in New Hampshire. Goshawk breeding areas were compared to randomly generated plots

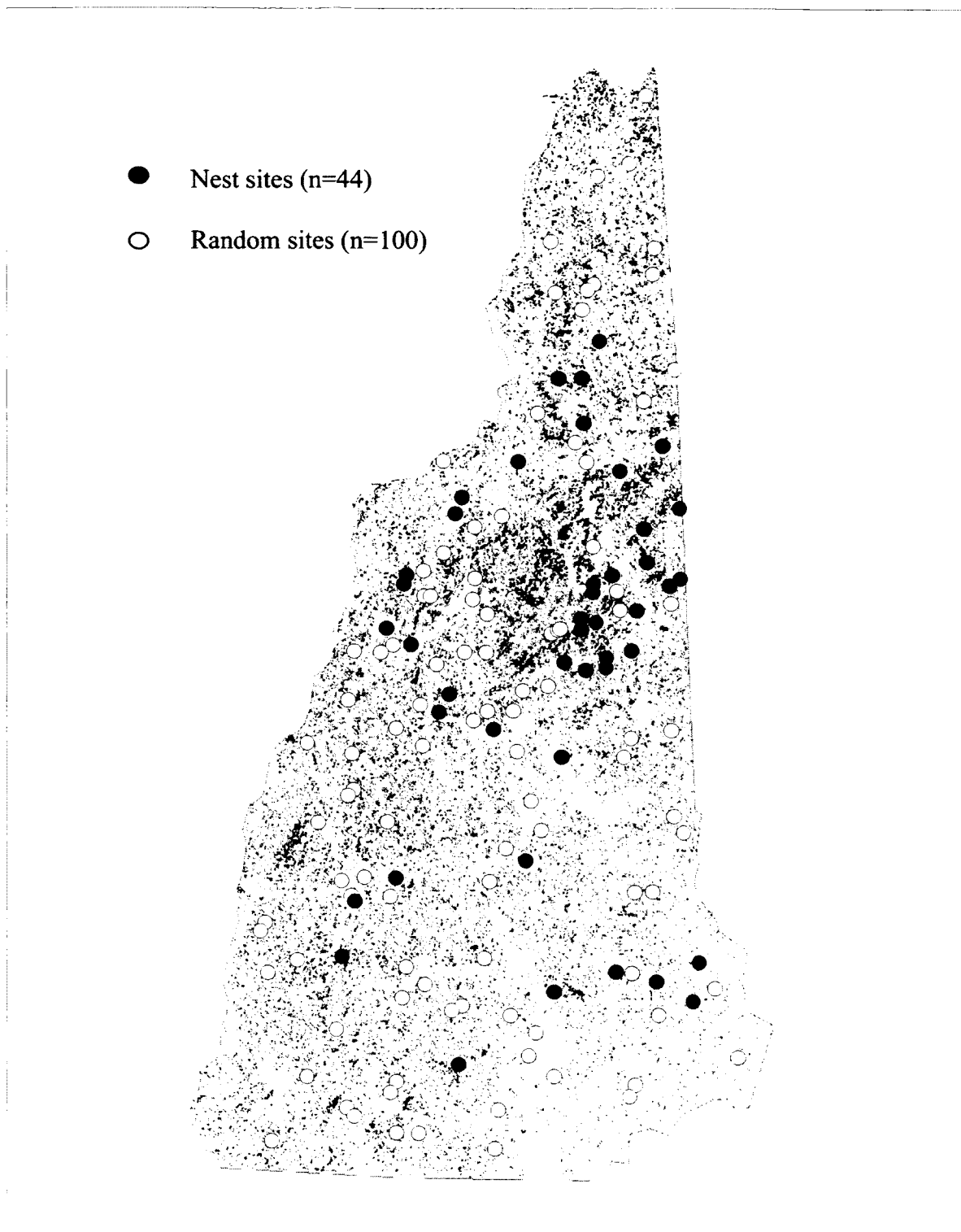


Figure 3. Northern goshawk nest locations and generated random points used to create study plots of goshawk breeding areas and available habitat in New Hampshire. New Hampshire Land Cover Data (NHLC) map from NHGRANIT [www.granite@unh.edu](http://www.granite@unh.edu) (Accessed 2 February 2008).

depicting available habitat. Study plots were created at four spatial scales for both breeding areas and available habitat.

All Geographic Information System (GIS) analyses were conducted using ArcGIS 9.2 software from Environmental Systems Research Institute (ESRI). I used ArcCatalog to manage GIS layers, and ArcMap to digitize boundaries, analyze data, and create graphics. I used existing, remotely sensed data of land cover composition from New Hampshire Land Cover Assessment (NHLC), created by the Complex Systems Research Center at the University of New Hampshire (Justice et al. 2002). NHLC is a digital land cover data set derived from a 30-meter resolution of Landsat 5 and 7 thematic mapper (TM) images. NHLC digital land cover classifications were created at 3 levels; level 1 is aggregated into a 7- class dataset, level 2 contains a partially aggregated 17 class dataset and level 3 is a 23-class dataset of non-aggregated land cover types (Table 1). The level 3 classification of NHLC was used for specificity of cover types (i.e., beech/oak and hay/pasture rather than forest and agriculture). NHLC data was acquired from the NH GRANIT (2002) website, a statewide GIS clearinghouse.

NH GRANIT Public/Conservation Lands data was used to determine status for all nest locations in relation to private, public and conservation land in New Hampshire. NH GRANIT data defines Public/Conservation Lands as parcels of more than 0.8 ha (2 acres) that are mostly undeveloped and protected from any future development.

### **Study Plots**

In this study, available habitat characterizes the landscape across the entire study area and may include areas used by the focal species (as described in the methodology of



Table 1. New Hampshire Land Cover (NHLC) Data classification scheme and error matrix for land cover in New Hampshire. User's accuracy represents when the map correctly describes the reference sites and producer's accuracy represents percentage of occurrences in which reference sites were assigned a correct label. Table created from the NHLC Final Report (Justice et al. 2002).

<b>Level 1 Classification</b> (Overall Accuracy 95.9%)	% of total state area	% Accuracy Producer	% Accuracy User
Developed	4.4	93.6	91.3
All Agriculture	4.1	96.2	95.6
Forest	77.6	99.0	97.5
Water	4.4	100.0	100.0
Wetland	3.1	94.3	95.0
Cleared/Other Open	6.4	89.9	94.4
Tundra	0.1	100.0	100.0
 <b>Level 2 Classification</b> (Overall Accuracy 88.4%)			
Residential/Commercial/Industrial	1.6	86.9	88.3
Transportation	2.8	100.0	85.0
Agriculture	4.4	95.0	95.8
Orchards	0.1	97.4	92.5
Deciduous Forest	32.9	90.7	94.8
Coniferous Forest	18.2	97.3	81.9
Mixed Forest	26.3	39.7	62.5
Alpine (Krummholz)	0.2	100.0	80.0
Water	4.4	100.0	100.0
Forested Wetland	1.1	74.3	86.7
Open Wetland	1.9	88.2	75.0
Tidal Wetland	0.1	100.0	100.0
Disturbed	0.4	90.0	90.0
Bedrock/Vegetated	0.4	100.0	100.0
Sand Dunes	0.1	100.0	100.0
Other Cleared	5.9	82.4	93.3
Tundra	0.1	100.0	100.0

Table 1. (cont.)

**Level 3 Classification**  
(Overall Accuracy 82.2%)

Residential/Commercial/Industrial	1.6	86.9	88.3
Transportation	2.8	100.0	85.0
Row Crops	0.3	94.6	88.3
Hay/Pasture	3.8	84.6	91.7
Orchards	0.1	97.4	92.5
Beech/Oak	14.4	68.1	53.3
Paper Birch/Aspen	4.1	28.6	28.6
Other Hardwood	14.4	53.2	70.0
White/Red Pine	7.4	90.7	81.7
Spruce/Fir	7.2	93.8	80.4
Hemlock	3.5	95.1	65.0
Pitch Pine	0.1	100.0	97.5
Mixed Forest	26.3	39.7	62.5
Alpine (Krummholz)	0.2	100.0	80.0
Water	4.4	100.0	100.0
Forested Wetland	1.1	74.3	86.7
Open Wetland	1.9	88.2	75.0
Tidal Wetland	0.1	100.0	100.0
Disturbed	0.4	90.0	90.0
Bedrock/Vegetative	0.1	100.0	100.0
Sand Dunes	< 0.1	100.0	100.0
Other Cleared	5.9	82.4	93.3
Tundra	0.1	100.0	100.0

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Jones 2001). To create study plots of available habitat, random points were generated using ArcMap random point generator tool ( $n = 100$ ) (Fig. 3). Each random point was the center location of circular polygons at four landscape scales 161(400 acres), 405 (1,000 acres), 809 (2,000 acres) and 1619 (4,000 acres) ha (Fig. 4) (Table 2). One hundred random points sufficiently covered the study area without creating significant overlap of polygons.

To create study plots of goshawk breeding areas, each nest site ( $n=44$ ) was the center location of circular polygons (Fig. 3) at the same four landscape scales used for available plots (Fig. 4) (Table 2). In breeding areas with alternate nests the centermost, or most active nest, was the center location.

Study plot sizes were chosen based on how breeding goshawks utilize the landscape, as depicted in the goshawk literature (Reynolds 1983, Reynolds et al. 1992, Kennedy et al. 1994, Squires and Reynolds 1997, and Boal et al. 2003) because true estimates of goshawk breeding territories in New Hampshire were beyond the scope of this study. The smallest study plot of 162 ha (400 acre), approximates the size of the nest site and the PFA combined (as described by Reynolds et al. 1992) and was used to depict core breeding areas (Fig. 4). The three larger study plots, 405 ha (1000 acre), 809 ha (2000 acre) and 1619 ha (4000 acre), represent variable depictions of the core breeding area and at least a portion of the foraging area (Fig. 4). The three larger plots were used to assess land cover changes in breeding areas as distance from the nest increased and to gain insight into the probable characteristics of goshawk foraging areas in New Hampshire.

Land cover composition within each circular study plot, for both breeding areas

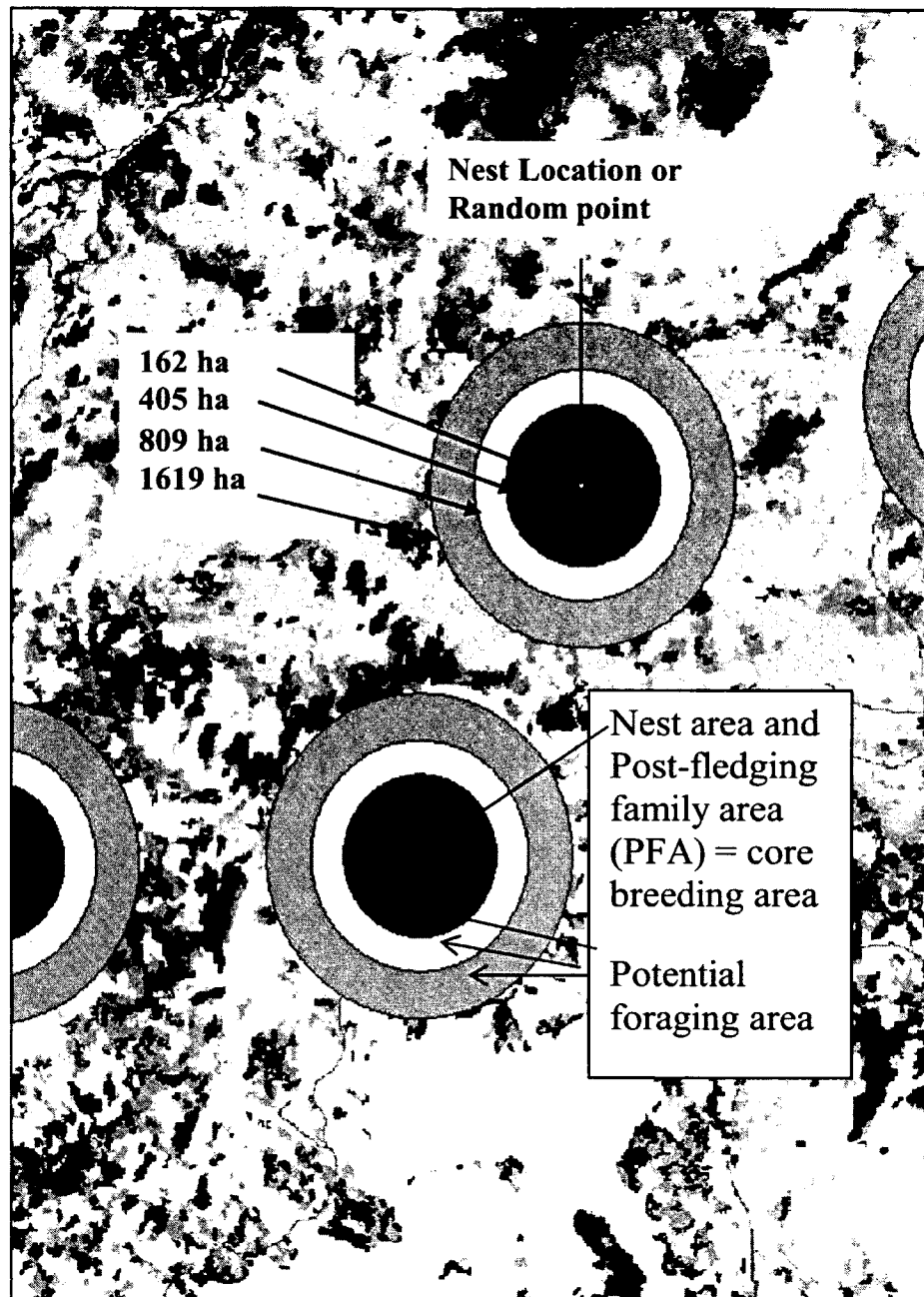


Figure 4. Circular polygons created at four landscapes scales surrounding goshawk nest trees and random points, used to characterize goshawk breeding areas and available habitat respectively, in New Hampshire. New Hampshire Land Cover Data (NHLC) map from NHGRANIT [www.granite@unh.edu](http://www.granite@unh.edu) (Accessed 2 February 2008). Graphic created in ArcGIS 9.2.

Table 2. Classification of study plots representing four polygon sizes for goshawk breeding areas and available habitat in New Hampshire.

<u>Study Plot</u>	<u>Polygon sizes</u> hectares	<u>Polygon sizes</u> (acres)
Breeding Area	162	(400)
Breeding Area	405	(1000)
Breeding Area	809	(2000)
Breeding Area	1618	(4000)
Available Habitat	162	(400)
Available Habitat	405	(1000)
Available Habitat	809	(2000)
Available Habitat	1618	(4000)

and available habitat, was tabulated using ArcMap spatial analyst zonal statistic tool. The mean percentage of cover type present within each plot was calculated. In cases where polygons overlapped, a new GIS layer was created to measure each plot as a separate unit. Although this may have created a minor issue with spatial independence in the largest polygons, given the limited extent that it occurred, this procedure likely had little effect on the results. Land cover classifications that did not generate sufficient data points were omitted from the analysis.

### **Topographical Analysis**

National Elevation Data (NED) from U.S. Geological Survey (USGS 2008), depicted at 1-arc second (approx. 30 meters) resolution (Gesch 2007), was used to compare elevation, slope and aspect at nest locations and random points. NED was used because it was created in a seamless format for ease of use.

### **Statistical Analysis**

JMP 8.0 statistical software (SAS 2008) was used to analyze data. For all statistical tests the  $\alpha$  was 0.05. A standard multivariate analysis of variance (MANOVA) with an identity response tested the null hypothesis of no difference in land cover characteristics between goshawk breeding areas and available habitat. A multivariate analysis was used because it can protect against a type I error that might occur with the use of multiple, independent ANOVAs. Significance was based on Hotelling-Lawley, a 2-group MANOVA test that allows for individual comparisons. Post hoc tests included a significant standard least squares analysis that identified specific land cover types where

differences existed. Student's t-tests with a 95% confidence interval were used to compare means of land cover types identified as statistically significant in the least squares analysis. There were no corrections for multiple comparisons, as these corrections tend to increase the chances of a type II error occurring (Gotelli and Ellison 2004).

Elevation, slope, and aspect measurements were centered on the nest tree in breeding areas and at each random point for available habitat plots. Mean elevation and percent slope were compared using t-tests assuming equal variances. A polar coordinates analysis was used to assess directional aspect of plots.

## CHAPTER III

### RESULTS

#### General Results

Of the 44 goshawk nest locations used in this analysis, 70.5% ( $n = 31$ ) were located either on public or conservation land (some conservation land is in private ownership) (Fig. 5) and 29.5% ( $n = 13$ ) were located on private (non-conservation) land. Initial identification of land cover types in either goshawk breeding areas or available habitat plots generated only 2 data points for alpine/krummholz, 3 data points for tidal wetlands, and no data for alpine tundra or sand dunes, therefore these 4 land cover classifications were not included in further analyses. Multivariate analysis of the remaining 19 land cover classifications showed that there was a statistical difference Hotelling-Lawley,  $F_{133, 2714} = 1.32, p = 0.009$  (Table 3) in the presence and composition of land cover types within goshawk breeding areas compared to available habitat. Least squares analysis revealed that statistical differences occurred within four land cover types. Least squares analysis showed breeding areas had on average a greater presence of white/red pine  $F_7 = 2.74, p = 0.008$  and birch/aspen  $F_7 = 2.13, p = 0.008$  and a lesser presence of hay/pasture  $F_7 = 3.88, p = 0.008$  and beech/oak  $F_7 = 2.98, p = 0.008$  (Table 4). Differences were most obvious at smaller scales in all cover types except birch/aspen, which had a slightly greater presence at the two larger scales.



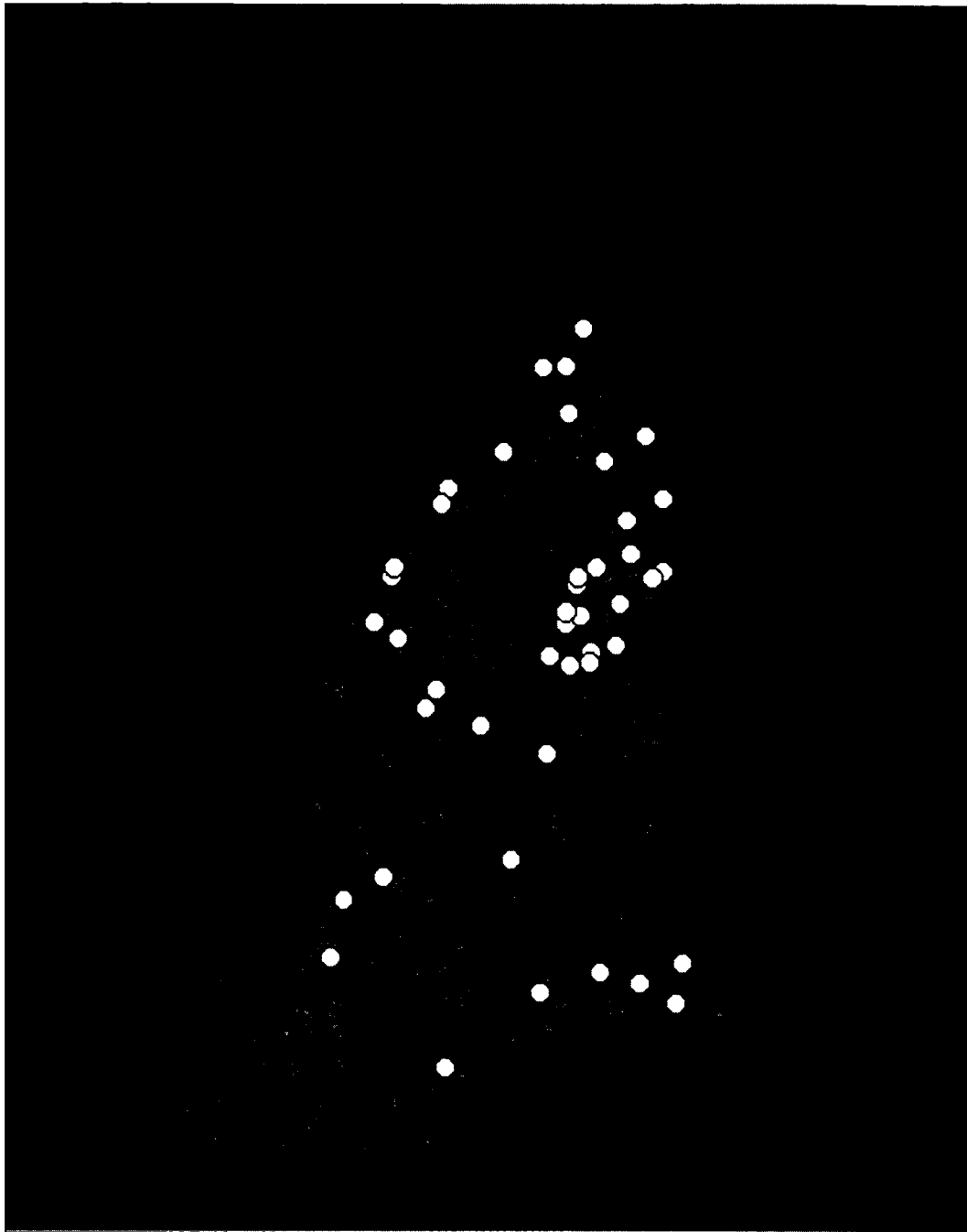


Figure 5. Location of northern goshawk breeding areas in relation to private, public and conservation land in New Hampshire. Public and conservation areas appear as light gray. Data acquired from NHGRANIT [www.granite@unh.edu](http://www.granite@unh.edu) (Accessed 2 February 2008).

Table 3. Results of a multivariate analysis, with an identity response, comparing land cover types (n=19) of goshawk breeding area plots (n=44) to available habitat plots (n=100) in New Hampshire. Comparisons of breeding areas to available habitat were conducted at four spatial scales: 161(400 acres), 405 (1,000 acres), 809 (2,000 acres) and 1619 (4,000 acres) ha.

<u>Whole Model</u>					
Test	Value	Approx. F	numerator DF	denominator DF	Prob>F
Hotelling-Lawley	0.320	1.321	133	2714.25	0.009
<u>Intercept</u>					
Test	Value	Exact F	numerator DF	denominator DF	Prob>F
F Test	271313.7	7853817	19	550	<0.001
<u>Polygon Treatment</u>					
Test	Value	Approx. F	Num DF	Den DF	Prob>F
Hotelling-Lawley	0.320	1.321	133	2714.25	0.009

The numerator degrees of freedom denotes between group df - number of groups minus 1  
The denominator degrees of freedom is the within group df - number of groups × (number of subjects minus 1)

Table 4. Least squares analysis of mean percentages of land cover types present within northern goshawk breeding areas compared to available habitat across the state of New Hampshire.

Land Cover Classification	DF	Sum of Squares	F Ratio	Prob > F
Residential/Commercial/Industrial	7	0.013	1.354	0.223
Transportation	7	0.018	1.791	0.087
Row Crops	7	0.000	0.894	0.510
Hay/Pasture	7	0.046	3.882	< 0.001*
Orchards	7	0.001	0.438	0.878
Beech/Oak	7	0.218	2.980	0.004*
Paper Birch/Aspen	7	0.080	2.127	0.039*
Other Hardwood	7	0.017	0.106	0.998
White/Red Pine	7	0.146	2.774	0.008*
Spruce/Fir	7	0.036	0.396	0.905
Hemlock	7	0.024	1.894	0.068
Pitch Pine	7	0.000	1.557	0.146
Mixed Forest	7	0.056	0.581	0.771
Water	7	0.008	0.333	0.939
Forested Wetland	7	0.001	0.189	0.988
Open Wetland	7	0.003	1.094	0.365
Disturbed	7	0.000	0.369	0.921
Bedrock/Vegetated	7	0.000	0.343	0.934
Other/Cleared	7	0.006	0.346	0.932

### **Topographical Analysis**

Nest sites were located at lower elevations compared to random points but differences were only marginally significant  $t_{142} = 1.93, p = 0.055$  (Fig. 6). The topographic gradient of goshawk breeding areas (measured as percent slope) was lower than found at available plots  $t_{142} = 2.42, p = 0.017$  (Fig. 7). Directional aspect of breeding plots showed no distinct differences compared to available plots (Fig. 8).

### **Land Cover Characteristics by Spatial Scale**

#### **162 Hectare (400 acre) Plots**

There was a lower percentage of hay/pasture (1.2%)  $t_{142} = 2.37, p = 0.018$  and beech/oak (9.5%)  $t_{142} = 3.31, p = 0.001$  (Table 5) cover types within breeding areas compared to available habitat (3.0% and 15.6% respectively). Breeding areas were composed of a higher percentage of white/red pine (13.1%) than was found in available habitat (8.2%)  $t_{142} = 3.1, p = 0.002$  (Table 5). Percentage of birch/aspen was higher within breeding areas (7.6%) compared to available habitat (5.3%) but the difference was only marginally significant  $t_{142} = 2.05, p = 0.09$  (Table 5).

#### **405 Hectare (1000 acre) Plots**

Mean presence of hay/pasture and beech/oak increased in both breeding areas (1.8% and 11.5% respectively) and available habitat (3.7% and 15.9% respectively) (Table 5) at the 405-ha scale, compared to the 162 ha plots. Both hay/pasture and beech/oak were still found less often within breeding areas  $t_{142} = 2.60, p = 0.009$ ;  $t_{142} = 2.34, p = 0.02$  respectively (Table 5) when compared to available habitat. Mean

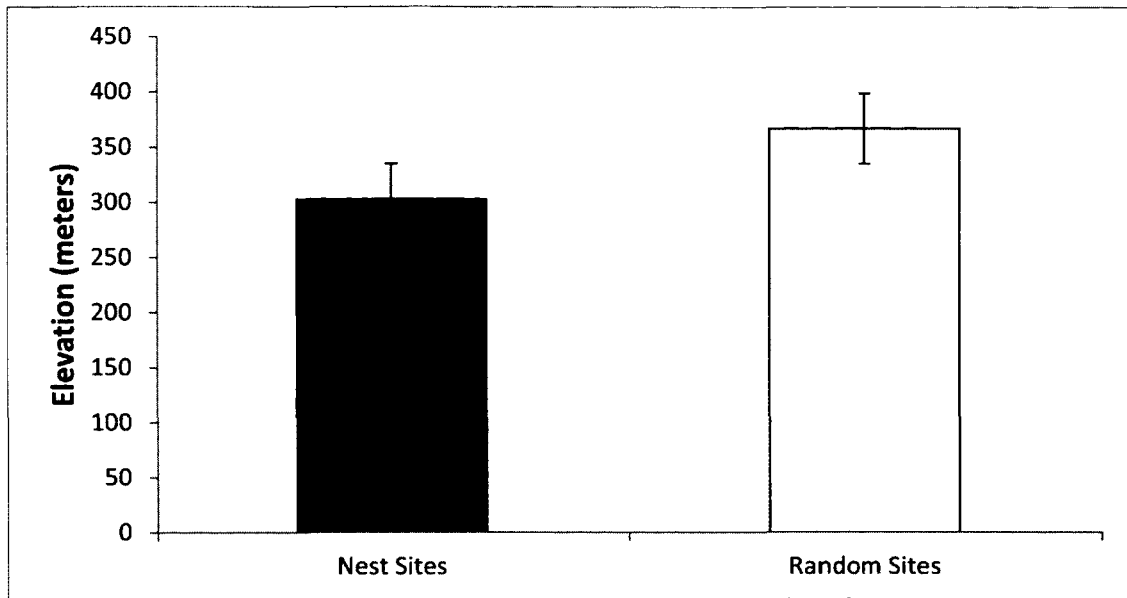


Figure 6. Mean elevation of northern goshawk nest site locations ( $n = 44$ ) and random points ( $n = 100$ ) in New Hampshire  $t_{142} = 1.93$ ,  $p = 0.055$ . Error bars show standard error.

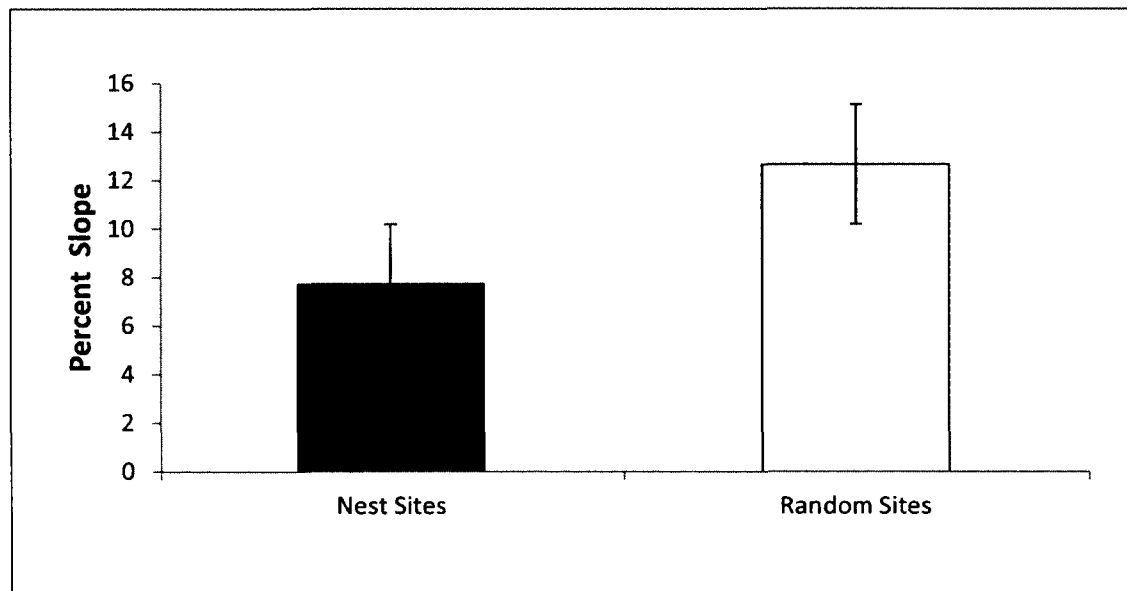
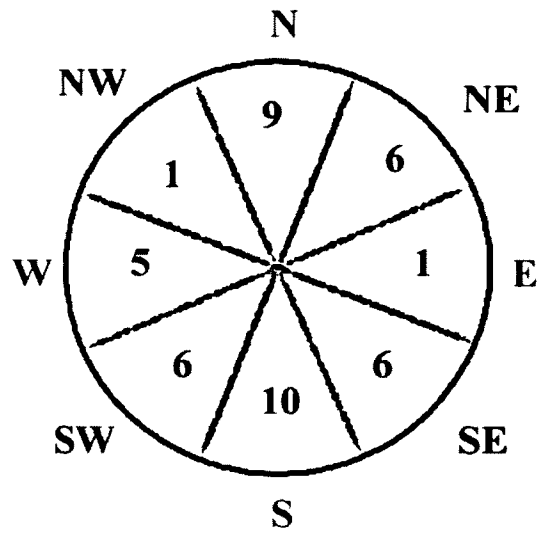


Figure 7. Mean percent slope of northern goshawk breeding plots ( $n = 44$ ) and available plots ( $n = 100$ ) in New Hampshire  $t_{142} = 2.42$ ,  $p = 0.017$ . Error bars show standard error.

a.



b.

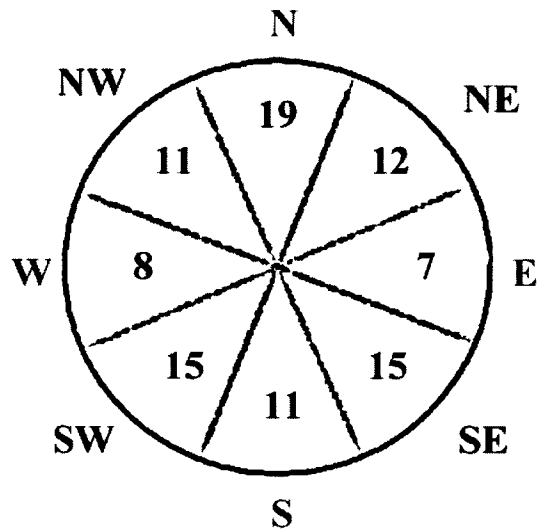


Figure 8. Directional aspect of (a) goshawk breeding areas (n=44) and (b) random plots (n=100) in New Hampshire. Value depicts number of sites within each category. No aspect was determined for 2 random plots on level ground.

Table 5. Comparison of mean percentages of land cover types present within goshawk breeding areas and available habitat across New Hampshire. Results based on Student's t-test with 95% confidence level.

Cover type	Polygon Size ha (acres)	Mean Breeding	Percentage Available	t-ratio	DF	Std Error	P Value
Hay/Pasture	162 (400)	1.2	3.0	2.37	142	0.01	0.018
	405 (1000)	1.8	3.8	2.60	142	0.01	0.009
	809 (2000)	2.2	4.1	1.34	142	0.01	0.013
	1619 (4000)	2.4	3.7	1.28	142	0.01	0.074
Beech/Oak	162 (400)	9.5	15.6	3.31	142	0.02	0.001
	405 (1000)	11.5	15.9	2.34	142	0.02	0.020
	809 (2000)	13.2	15.6	1.34	142	0.02	0.182
	1619 (4000)	14.2	15.8	0.88	142	0.02	0.380
White/Red Pine	162 (400)	13.1	8.2	3.10	142	0.02	0.002
	405 (1000)	11.0	7.7	2.10	142	0.02	0.036
	809 (2000)	9.3	7.6	1.05	142	0.01	0.294
	1619 (4000)	8.5	7.5	0.62	142	0.01	0.533
Birch/Aspen	162 (400)	7.6	5.3	1.70	142	0.01	0.090
	405 (1000)	7.7	5.1	1.94	142	0.01	0.052
	809 (2000)	7.6	5.0	1.99	142	0.01	0.048
	1619 (4000)	7.7	4.9	2.05	142	0.01	0.041

presence of white/red pine decreased in both breeding areas (11.0%) and available habitat (7.7%) but was still found more often within breeding areas  $t_{142} = 2.1, p = 0.036$  (Table 5). The mean percentage of birch/aspen was similar to that found in the 162-ha plots in both breeding areas (7.7%) and available habitat (5.1%) with differences between breeding areas and available habitat still only marginally significant  $t_{142} = 1.94, p = 0.052$  (Table 5).

#### **809 Hectare (2000 acre) Plots**

On average breeding areas in the 809 ha plots contained a slightly higher percentage of hay/pasture (2.2%) (Table 5) than breeding areas in the 162 and 405 ha plots, but this cover type was still present in breeding areas less often than would be expected ( $t(142) = 1.34, p = 0.013$ ) compared to available habitat (4.1%) (Table 5). The percentage of beech/oak present did not differ statistically between breeding areas (13.2%) and available habitat (15.6%)  $t_{142} = 1.34, p = 0.182$ . Mean percent of white/red pine in breeding areas (9.3%) was higher than the mean percent in available habitat (7.6%) (Table 5) but these results were not statistically different  $t_{142} = 1.05, p = 0.294$ . Birch/aspen was present more often than expected within breeding areas (7.6%) compared to available habitat (5.0%)  $t_{142} = 1.99, p = 0.048$  (Table 5).

#### **1619 Hectare (4000 acre) Plots**

At this spatial scale there were no statistical differences between breeding areas and available habitat for hay/pasture, beech/oak or white/red pine cover types (Table 5). There was a statistically higher presence of birch/aspen within breeding areas (7.7 %) compared to available habitat (4.9%)  $t_{142} = 2.05, p = 0.041$  (Table 5).



### **Spatial Patterns Across Scales**

There were distinct spatial patterns in the composition of land cover types both within and between goshawk breeding areas and available habitat. These patterns showed statistical differences in the four land cover types identified in the least squares analysis (Table 4) and the Student's t-test (Table 5) and were most distinguishable within the two smaller landscape scales (Table 6). The presence of hay/pasture was lower within breeding areas at all spatial scales and increased in presence as plot size increased (Fig.9). Hay/pasture was present less than would be expected within breeding areas in all but the largest spatial scale (Table 6).

Beech/oak presence increased slightly in breeding areas as plot size increased but mean percentages remained stable within available habitat plots across all scales (Fig. 10). Beech/oak presence was higher in available habitat compared to breeding areas at all scales (Fig. 10) but this was only statistically significant at the two smallest scales (Table 6).

White/red pine demonstrated almost an inverse pattern compared to the hay/pasture and beech/oak cover types with the presence of pine decreasing as scale increased in both plot types (Table 5). At the two smaller scales pine was present within breeding areas more often than expected compared to available habitat. No statistical difference in the presence of pine was found at the two larger scales (Table 6).

Birch/aspen displayed a unique pattern compared to the three cover types described above. This was the only cover type for which there were no statistical differences at the two smaller scales. Presence of birch/aspen remained relatively stable

Table 6. Spatial patterns of land cover presence in New Hampshire within and between goshawk breeding areas and available habitat at four landscape scales.

Cover type	Spatial Scale ha (acres)			
	162 (400)	405 (1000)	809 (2000)	1619 (4000)
Hay/Pasture	L	L	L	NS
Beech/Oak	L	L	NS	NS
White/Red Pine	H	H	NS	NS
Birch/Aspen	NS	NS	H	H

L = Cover type found less often in breeding areas.

H = Cover type found more often in breeding areas.

NS = No statistical significance in cover type found between breeding areas and available habitat.

across all spatial scales within both breeding areas and available habitat with a slight decrease of presence within available habitat as scale increased (Fig. 12). Statistical differences were seen at the two larger landscape scales (Table 6) with a higher mean percentage found within breeding areas (Table 5).

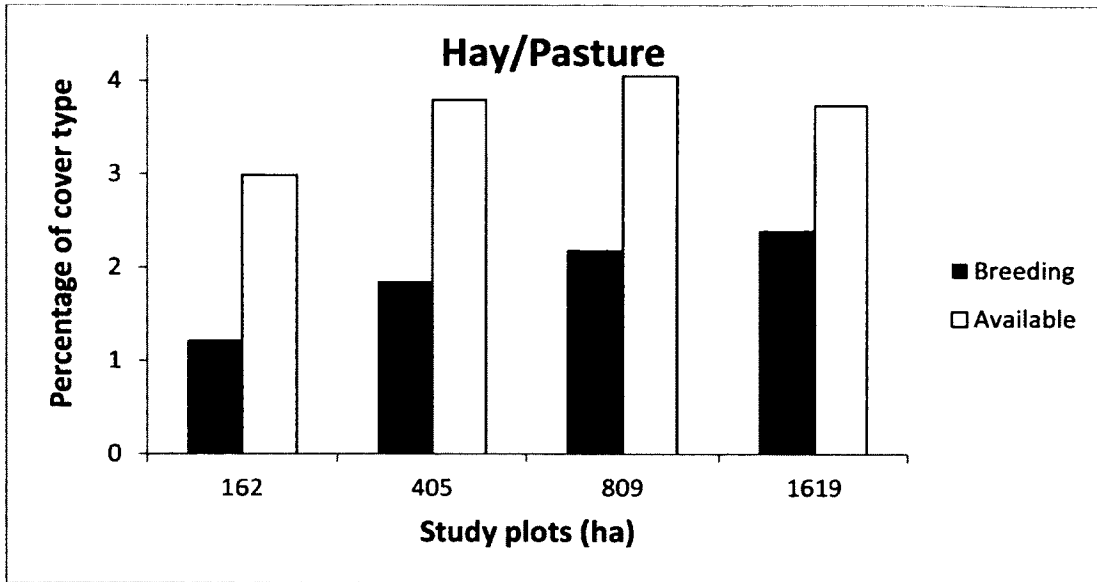


Figure 9. Mean percentages of hay/pasture cover type within goshawk breeding areas and available habitat in New Hampshire at four spatial scales. Error bars show standard error.

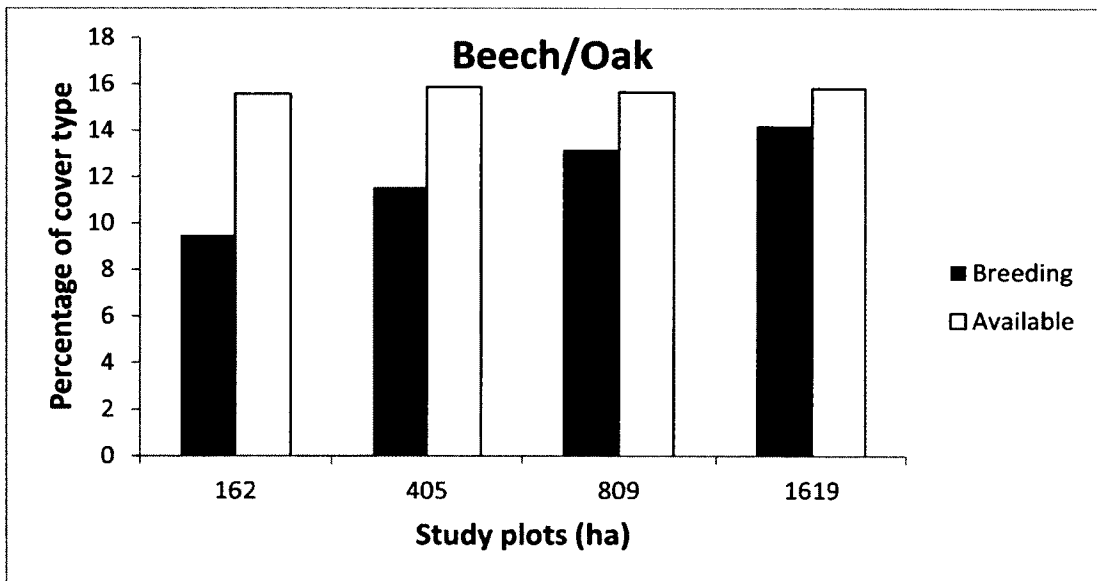


Figure 10. Mean percentages of beech/oak cover type within goshawk breeding areas and available habitat in New Hampshire at four spatial scales. Error bars show standard error.

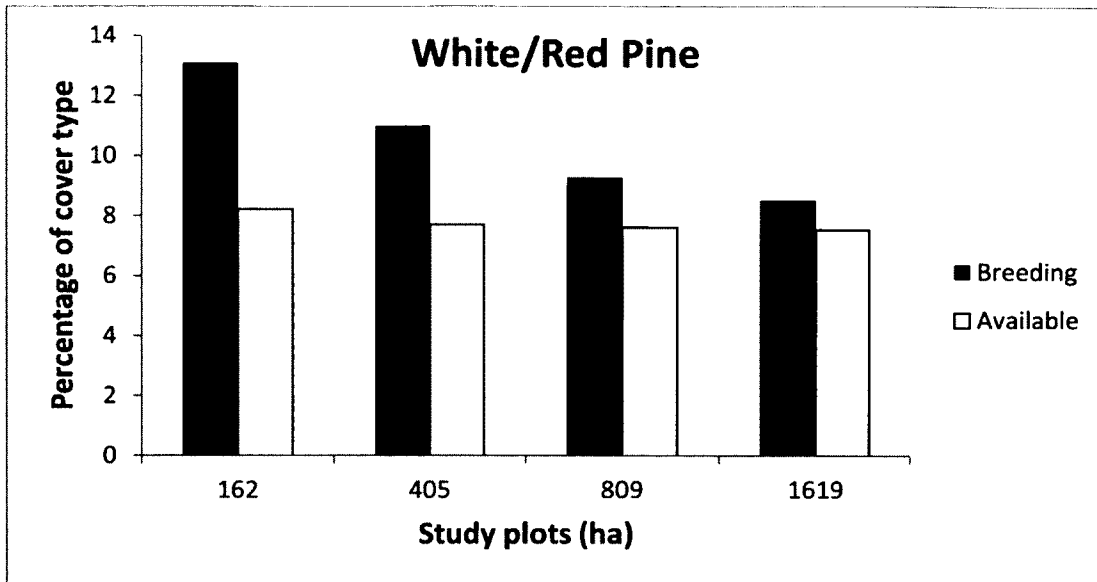


Figure 11. Mean percentages of white/red pine cover type within goshawk breeding areas and available habitat in New Hampshire at four spatial scales. Error bars show standard error.

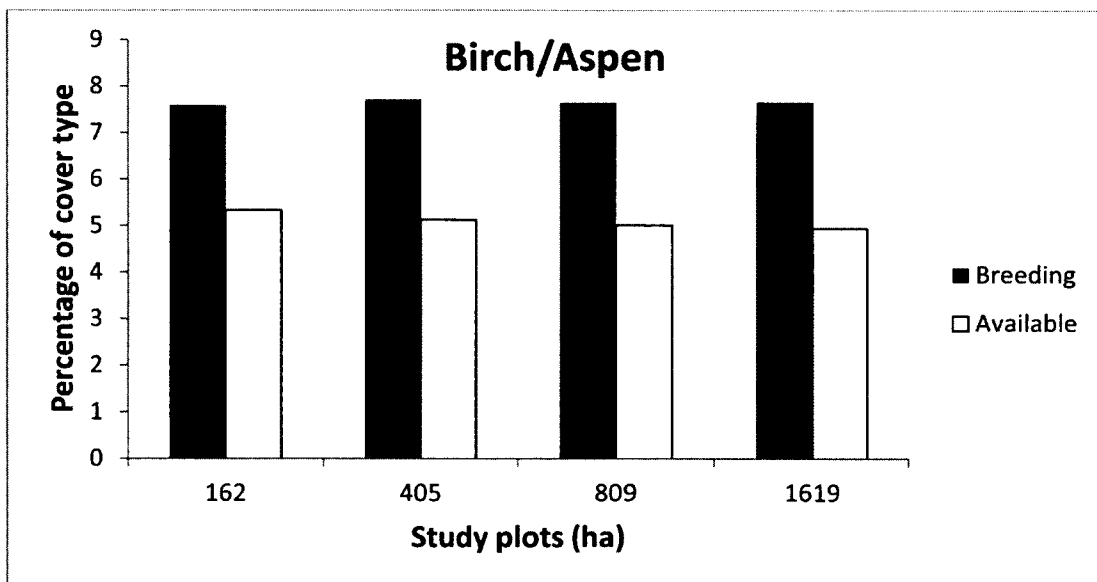


Figure 12. Mean percentages of birch/aspen cover type within goshawk breeding areas and available habitat in New Hampshire at four spatial scales. Error bars show standard error.

## **CHAPTER IV**

### **DISCUSSION**

To date this is one of the largest scale landscape studies of goshawk breeding habitat conducted in the U.S. and the only study of this scope and scale in the eastern region of the country. Results of this study showed distinct differences in composition of goshawk breeding areas when compared to the general landscape across New Hampshire. Three of the four cover types found to be statistically significant in this study showed distinct differences at the two smaller landscape scales. As distance from the nest increased, goshawk breeding areas began to look similar to the surrounding landscape.

Other studies have shown similar patterns of distinct characteristics at the core of goshawk breeding areas that diminished with increasing distance from the nest. In central Washington and northeastern Oregon McGrath et al. (2003) compared stand development, vegetative structure and topographic position of 82 active goshawk nesting areas at eight spatial scales between 1 and 170 ha. They found basal area and topographic position were most reliable in discriminating between nest sites and random sites and these differences decreased with increasing area. Daw and DeStefano (2001) compared 22 goshawk nest sites in Oregon to random sites at five spatial scales from 12 to 170 ha. Their results showed late stage forest structure and dense canopy cover were important close to the nest but decreased in relative abundance with increased distance. In Alaska Iverson et al. (1996) analyzed color and black-and-white aerial photographs and found less variability at goshawk nest sites in 30 ha plots compared to 160 ha plots

when comparing nest sites to random plots. The scales used to analyze goshawk habitat in the studies mentioned above are much smaller than those used in New Hampshire but results from these studies do support the theory that goshawks are using breeding areas with distinct characteristics compared to the general landscape. Differences in breeding areas are most significant immediately surrounding the nest and less noticeable as distance from the nest increases.

### **Topography**

Digital elevation data for goshawk nest locations showed that mean elevation was lower at nest sites than at random sites but this was only marginally significant (Fig. 6). Nests were located on gentler slopes (Fig. 7) than was found on random plots but no selection for directional aspect (Fig.8) was found at nest sites.

These results are in stark contrast to a study in New Jersey and southeastern New York where no difference in slope was found between nest sites and random sites; nests were located at significantly higher elevations than were found on random plots; and goshawks selected against southerly aspects (Bosakowski and Speiser 1994). The differences between the topographical data in this study and results from New Jersey and southeastern New York may be due to local forest conditions. Nests in New York and New Jersey were likely found at higher elevations because that is where the largest wilderness tracts occurred (Bosakowski and Speiser 1994). The study site in Bosakowski and Speiser (1994) had much lower variation in elevation (170-460 m) (Speiser and Bosakowski 1987) compared to New Hampshire. Lower elevation could account for the lack of significant difference in slope. Sites at lower elevations are also more likely to be

warmer and goshawks may select against southern aspects at these sites to protect the nest from overexposure to solar radiation (Reynolds et al.1982, Hall 1984, McGrath et al. 2003).

The literature shows widely differing results for directional aspect of goshawk nest sites across regions of the U.S. Preference for a northern exposure at goshawk nest sites was reported in Oregon (Reynolds et al. 1982) and western Montana (Hayward and Escaño 1989). In northern Nevada nest sites were generally found with a northern or eastern aspect (Younk and Bechard 1994) and in Wyoming (Squires and Ruggiero 1996) no preference for site aspect was found. Squires and Ruggiero (1996) did note that the nest in relation to the bole of the nest tree was southerly. In interior Alaska 64% of goshawk nests were located on southern aspects (McGowan 1975, as reported in Kennedy 2003).

The disparate results in directional aspect for nest sites may be due to varying microclimates at the nest (Reynolds et al. 1982, Hall 1984). It has been hypothesized that nest site selection stems from adaptations to build nests in a manner that protects it from weather extremes (Reynolds et al.1982, McGrath et al. 2003). At warmer sites, northerly aspects may help protect brooding females and nestlings from extreme exposure to solar radiation (Reynolds et al.1982); whereas goshawks nesting in northern latitudes like Alaska may select southern aspects (McGowan 1975) because of their warmer temperatures.

### **Hay/Pasture**

Hay/pasture has one of the highest user accuracy rates of all cover types classified



(91.7%) (Table 1) and likely represents the strongest results of this analysis. Goshawks breeding areas contained percentages of hay/pasture lower than expected at the nest site in all but the largest spatial scale suggesting avoidance of this cover type with potential avoidance diminishing as scale increased (Table 6).

Little information pertaining to agricultural land within goshawk breeding home ranges in the U.S. exists in the literature. In Sweden (Widen 1989) and England (Kenward and Widen 1989), researchers observed goshawks wintering in forests interspersed with clear cuts or agricultural lands and reported most foraging took place in patches of mature forest or forest edge. In Finland Tornberg and Colpaert (2001) noted that centers for goshawk winter ranges were located close to human habitation but birds preferred deciduous and mature conifer forests and avoided open area such as large fields. Agricultural areas and some open habitat interspersed within suitable habitat may not have a negative impact on goshawks as long as adequate abundance of prey and vegetative structure conducive to goshawk nesting and foraging strategies are present (Kenward 1982, Widen 1994). Although goshawks appear to avoid hay/pasture in core breeding areas this cover type may have little influence on breeding goshawks in New Hampshire where total agricultural area consists of only 4.1% (Table 1) of total area in the state.

### **Beech/Oak**

The beech/oak cover type comprises 18.5% of total forest area in New Hampshire (Justice et al. 2002). Reasons for goshawks selecting against this forest type within nesting areas are unclear. The beech/oak cover type may not create the forest structure or

tree architecture, such as basket-shaped branching, necessary for successful goshawk nest building. Data for goshawk nests in New Hampshire shows that the occurrence of goshawk nests in either beech or oak trees is very low (M.Yamasaki, unpubl. data). With a low accuracy rate (user's accuracy of 53.3%) it is also possible that this cover type was confused with other hardwoods (Justice et al. 2002).

### **White/Red Pine**

The most consequential finding of this study was of the white/red pine cover type. Breeding goshawks appeared to have a strong affinity for sites with pine cover, as this was a major component at the core of breeding areas. On average white/red pine was present in higher percentages in breeding areas at all spatial scales (Table 5) and was found more than would be expected at the two smaller scales (Table 6). In the 162 and 405 ha plots pine was present in breeding areas in greater percentages (13% and 11% (Table 5), respectively) than is found on average across the state. In New Hampshire white/red pine is less than 10% of total forested area (Justice et al. 2002), and only 7.4% (Table 1) of total land area.

Results of the pine cover type in this study are supported by the unpublished stand-level data from which the goshawk nest locations for this study originated (M. Yamasaki, USDA Forest Service, pers. comm.). The stand-level data, taken on the ground, for 56 nests (including alternate nests) in New Hampshire and southern Maine showed nearly half (48%) of all nests were built in white pine trees and most nest sites (86%) were located within stands classified as white pine stands containing greater than 50% of the basal area in white pine. The ground data combined with the spatial analysis

of this study strongly demonstrates the importance of white pine at the core of goshawk breeding areas in New Hampshire, especially at the stand level.

Validity of any land cover analysis conducted with remotely sensed data depends on the accuracy of the dataset used in the assessment (Congalton 1991). The NHLC digital data used in this assessment was highly successful in identifying white/red pine with a producer's accuracy of 90.7% and a user's accuracy of 81.7% (Table 1). It should be noted that, based on topographic information used for the general classification of NHLC data, some white/red pine forest classes, at northern latitudes (north of the White Mountains) with elevations > 457 m (>1500 feet), were recoded to the spruce/fir classification (Justice et al. 2002). Some nest sites used in this study were located at these higher elevation, northern latitudes therefore it is possible that the white/red pine cover type in goshawk breeding areas was underestimated.

The presence of white pine in New Hampshire is likely due to disturbance from early clearing and agricultural abandonment in the region (Leak and Yamasaki 2010). White pine is difficult to regenerate and is easily out-competed by hardwood trees on moist, nutrient rich soils (Leak and Riddell 1979). In New England, white pine competes best and is able to persist on outwash habitat (dry sandy or gravel soils) (Leak and Riddell 1979). White pine stands in the New England region have been maturing in recent decades and stand regeneration rates appear to be too slow to sustain current volumes (Leak et al. 1995). Without disturbance regimes as part of a management strategy to assist regeneration young white pine stands will not replace older stands that are harvested or die off causing white pine to decline over time (Leak et al. 1995, Leak and Yamasaki 2010).

White pine is an economically significant resource in New Hampshire, at < 10 % of forest cover (Justice et al. 2002) it represents close to 50% of large timber (27.9 cm (11 inches) or greater) harvested in the state annually (SPNHF 2005). Because goshawks utilize areas with high densities of white pine, the economic value of white pine in New Hampshire could potentially create competition between human needs and goshawk breeding requirements.

Dry, sandy sites, where white pine is often found in New Hampshire, is also a preferred soil type for housing and development in the state of New Hampshire (SPNHF 2005). Approximately 50% of this habitat type is located in the southeastern region of the state where significant human development has already occurred (SPNHF 2005). In New Hampshire, development may be a greater risk to goshawk habitat than forest management practices like timber harvesting.

To maintain goshawk breeding habitat in New Hampshire intensive silvicultural strategies, such as releasing overtopped pine seedlings, may be needed to aid in the regeneration of white pine (Leak et al. 1995). Protection of dry, sandy or gravel soils by slowing human development on these soil types may also help to protect the goshawk's future in the state.

While results of this study show that the white/red pine cover type is an important component of goshawk breeding-habitat in New Hampshire it is unclear why goshawks might be selecting these sites. Goshawks nest in a variety of forest cover types across regions (Squires and Reynolds 1997) and build nests in a variety of tree species. In Oregon Reynolds et al. (1982) found 41 out of 69 nests were built in lodgepole pine; Hayward and Escaño (1989) found nests most often in coniferous species in Montana and

northern Idaho; Boal et al. (2005b) reported 94% of nests, within 43 nesting stands, were built in deciduous trees, most of which were in aspen or birch. In the eastern region of the U.S., Speiser and Bosakowski (1987) found 82% of 22 nests located in deciduous trees, mainly beech (27%) and birch (23%), in New Jersey and southeastern New York. In Wyoming Squires and Ruggiero (1996) found no preference between deciduous or coniferous species in breeding goshawks and nest trees were used in proportion to their availability within the surrounding landscape. It may be that goshawks are selecting breeding areas based on vegetative structure and topographical features not measured in this study.

### **Birch/Aspen**

Birch/aspen had a greater presence in breeding areas at all spatial scales and was found more than expected in the two largest scales (Table 6). This was the only cover type that showed statistical significance at the larger scales that diminished as scale decreased.

Birch/aspen is an ephemeral forest type that changes with forest growth and succession (Dessecker and McAuley 2001, Leak and Yamasaki 2010). The herb-shrub layer lasts only 1-2 years and individual trees generally die within 75 (aspen) to 100 (birch) years (DeGraaf et al. 2006). Reliant on disturbance (e.g. fire, windthrow, timber harvest) to maintain its presence, left undisturbed it will rapidly be replaced by several late successional or climax species (DeGraaf et al. 2006). This cover type is classified as early successional habitat in New England and tends to be biologically diverse,

containing species like hare (Litvaitis 2001) and grouse (Dessecker and McAuley 2001), common prey species of goshawks (Reynolds et al. 1992).

One major caveat to the birch/aspen results in this analysis is the inability of NHLC satellite data to accurately distinguish it. Birch/aspen had only a 28.6% user's accuracy, compared to 91.7% for hay/pasture, 53.3% for beech/oak and 81.7% for red/white pine (Table 1) (Justice et al. 2002). The small sample size of birch/aspen (Table 4) is cited as one of the main reasons for the low accuracy classification in the dataset (Justice et al. 2002); therefore, it is not possible to draw any definitive conclusions relating to birch/aspen cover type in goshawk breeding habitat in New Hampshire. In New England early successional habitat in the region is in decline due to aging forests, alteration of natural disturbance (e.g. fire suppression) (Litvaitis 1993, Trani et al. 2001) and changes in forest management strategies (Leak and Yamasaki 2010) like smaller openings instead of clearcutting . The loss of prey species due to declines in early successional habitats may negatively affect top-level predators (Litvaitis 1993) like goshawks and warrants future investigation of the birch/aspen cover type.

## **CHAPTER V**

### **CONCLUSIONS**

The results of this study combined with the variety of forest conditions and cover types reportedly used by goshawks in other regions of the U.S. suggest that goshawks are choosing nest sites based, at least partially, on landscape-scale patterns and processes rather than solely on stand-level characteristics (McGrath et al. 2003). The high variability of forest types and local conditions are strong evidence that the goshawk has developed regional specializations in the selection and utilization of breeding habitat (Penteriani 2002, Bosakowski 1999).

Penteriani (2002) does caution that the variability in local forest conditions and topography used by breeding goshawks across regions could also indicate that goshawks are using the landscape in an opportunistic manner rather than selecting for specific habitat characteristics. Squires and Reynolds (1997) state that although goshawk nests are found in areas that contain specific vegetative and topographical characteristics they are often considered habitat generalists at large spatial scales. These assumptions indicate that goshawks may be adaptable to at least some changes in the landscape.

This analysis centers on the habits of northern goshawks breeding in the state of New Hampshire. While this study describes some of the local environmental conditions within New England, results are not necessarily representative of other New England states. Future research on goshawks in New Hampshire should include a habitat suitability analysis based on the results of this study and the unpublished habitat data

used as the source for the goshawk nest sites analyzed here. A habitat suitability model could aid land managers and biologists in locating goshawk nests more efficiently by narrowing search areas based on habitat characteristics. This research should also be expanded to find the best model for studying goshawk nesting habitat in other states within the region.



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